IN REPLY REFER TO

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

HAWAIIAN VOLCANO OBSERVATORY

HAWAII NATIONAL PARK, HAWAII 96718

May 22, 1975

Mr. David Buchart
Department of Land and Natural Resources
State of Hawaii
P. O. Box 621
Honolulu, Hawaii 96809

Dear Dave:

Enclosed are copies of the environmental assessments that were prepared for the Keller (NSF-funded) drill hole, the Kilauea Iki lava lake drilling, and the Sulphur Bank drilling. In the environmental assessment for the Keller hole, appendixes B, C, and D include the Letter of Agreement and other documents bearing on administrative procedures. I hope that the enclosed materials will be of some aid as you and others begin the necessary legwork for the upcoming Hawaii Geothermal Project's drilling in Kilauea's lower east rift.

It was good seeing you again, and please extend my regards to George Stepp.

Aloha,

Robert I. Tilling
Scientist-in-Charge

Enclosures

Environmental Assessment

of an

Investigation of the Hydrothermal System

at Kilauea Volcano, Hawaii

Prepared by

U. S. Geological Survey

Washington, D. C.

January 1973

SUMMARY

1. Type of action (X) Administrative ( ) Legislative

2. Brief description of action

A test well 3000 to 3500 feet in depth is proposed to be drilled 0.7 miles south of Halemaumau crater in Hawaii Volcanoes National Park, Island of Hawaii. It represents the first attempt to drill above a magma chamber of an active volcano to test the hydrologic and physical environment. Geological and geophysical test will also be performed in the area.

3. Summary of environmental impact and adverse environmental effects

The experimental test hole will be sited in an existing gravel pit served by existing roads closed to the general public. The area is in a National Park frequented by sightseers, therefore visual impact is important; however, as the drill site is 2000 feet from the nearest public road and over a slight rise, this impact will be minimal. The area is in the fume belt from Halemaumau Crater and fumes from the crater may present a health hazard to drillers during certain wind conditions.

Although not probable, an accident in the form of a blowout from high steam or magmatic pressures is possible. Stringent precautions are being taken to insure that this does not happen.

4. Alternatives considered

a. Other methods of investigation

b. No drill hole

5. List of entities from whom comments have been solicited or received

The environmental effects of the proposed action have been the subject of three interagency meetings held between the Geological Survey and National Park Service. A record of these meetings is attached as Appendix D.

Additional comments were solicited from Geological Survey and Park Service personnel with special knowledge or expertise related to the study.

CONTENTS

Environmental Impact Analysis of an Investigation of the Hydrothermal System at Kilauea Volcano, Hawaii

1. DESCRIPTION OF THE PROPOSAL

The National Science Foundation under the RANN (Research Applied to the National Needs) program has funded a research proposal (NSF Proposal No. P213232) submitted by Dr. George V. Keller, of the Colorado School of Mines, to use Kilauea Volcano, Hawaii as a laboratory to evaluate mechanism that may be important in hydrothermal systems, such as physical characteristics and ground water dynamics in the vicinity of a magma chamber (appendix A). A major part of the proposal, and only part with an environmental impact, involves the drilling of a test hole at a site selected to have the best chance of intersecting a convection cell of hydrothermal origin above Kilauea magma chamber. The proposal also includes geophysical surveys and tests in the summit area of the volcano, physical tests in the drill hole, and measurements on recovered samples.

The investigation is estimated to take approximately one year to complete and the drilling of the hole from three to six months. The results of the test will have implications on the development of geothermal energy from basaltic volcanic sources, therefore the study is important both for the island of Hawaii and for many geologically similar areas of the world. To date, all commercial power development utilizing geothermal energy has been associated with silicic volcanism.

The study is proposed to take place near Kilauea summit in Hawaii Volcanoes National Park on the island of Hawaii. The area was selected from geophysical evidence accumulated during investigations associated with basic research on volcanoes conducted by the U.S. Geological Survey at the Hawaiian Volcano Observatory. Several separate lines of evidence indicate that a shallow magma reservoir exists near the summit and that conditions necessary for a hydrothermal convection cell above the magma chamber may also exist. Ground deformation studies (Fiske and Kinoshita, 1969) have pointed up three areas of deformation associated with the eruptive activity of the 1967-1968 eruption. An analysis of the deformation indicates that it can be explained by the expansion of a magma chamber located at a depth of two or three kilometers beneath the surface. Electrical Surveys by Jackson and Keller (1972) show that a mound of material with very low resistivity is located within 900 meters of the surface, corresponding horizontally with the major center of deformation observed by Fiske and Kinoshita (1969). Jackson and Keller believe that the low resistivity could best be explained by a mass of rock saturated with highly saline hot water, such as may be present in an active convection cell above the magma chamber. This is, in part, also suggested by a zone of microseismicity concentrated near the resistivity anomaly and center of

Figure 1. - Topographic map of the Kilauea crater area showing drill site location.

inflation (Koyanagi and Endo, 1971) which lies above a zone of deeper earthquakes believed to be associated with the movement of magma.

Scientifically, there is a great advantage for utilizing the Hawaii Volcanoes National Park for the experiment site. Kilauea Volcano is already the most intensely studied and best understood volcano in the world. The location of the drill hole on National Park property assures that if a geothermal system of potential economic value is discovered, it will never be used to produce power, as lands administered by the National Park Service are specifically excluded from geothermal leasing under the Geothermal Steam Act of 1970. This assures that the area will remain a prototype for testing geothermal exploration and evaluation techniques for many years and that no commercial development of power will take place in the park.

Relationship of the drill hole to research activities at the Hawaiian Volcano Observatory

The Hawaiian Volcano Observatory on the rim of Kilauea caldera, currently operated by the U. S. Geological Survey, has existed for more than a half century. At the present time all that is known about the internal structure of the volcano is information that can be derived from surface geology, geophysical evidence, and exposures along the walls of the collapsed craters. Therefore, the Geological Survey has a strong interest in the proposed drill hole, both because of its promise of developing a better understanding of hydrothermal systems and because of the opportunity that the proposed drill hole presents in gaining a better understanding of the structure, petrology, hydrology, and other physical characteristics of the volcano.

In order to express the Geological Survey's strong interest in the drill hole and to help assure that the project would be funded, the Director of the Geological Survey in a letter dated May 5, 1972, to Dr. Jesse Denton of the Division of Advanced Technology Applications of the National Science Foundation, offered the Survey's assistance in the project by assuming the responsibility of preparing an environmental evaluation. The environmental effects of the proposed drilling were carefully considered by the staff of the Hawaiian Volcano Observatory and the Hawaii Volcanoes

National Park before the Geological Survey and National Park Service were willing to approve submittal to the proposal to the National Science Foundation.

Accordingly, with the submittal of the proposal, a Letter of Agreement was drawn up between the Principal Investigator, George V. Keller of the Colorado School of Mines, the Geological Survey, and the National Park Service, outlining the respective rights, responsibilities and duties of each party. A copy of this agreement is included with this declaration as Appendix B.

This letter of Agreement gives the Principal Investigator all responsibility and authority for administration of the drilling contract and bore-hole testing subcontracts, and the responsibility for assuring that drilling procedures are effective and safe and that proper drilling practices are followed. It gives the Geological Survey and National Park Service the right to review and approve all contracts and sub-contracts, and to assure that the site selected meets their approval as to scientific, technical, environmental, and aesthetic suitability. The Geological Survey and National Park Service have ultimate veto power if any phase of the program is not carried out to their satisfaction. It also defines scientific responsibilities of the Geological Survey and Principal Investigator, and assures data sharing and publication rights for each party.

II. DESCRIPTION OF THE ENVIRONMENT

Location

The project area lies in the Hawaii Volcanoes National Park in which the dominant features are the volcanoes of Mauna Loa and Kilauea. Kilauea volcano is one of the most active volcanoes in the world. Two features that made this volcano even more famous were the presence of an almost continuously active lake of lava at Halemaumau, the large crater within Kilauea caldera, throughout the 19th and first part of the 20th century, and the non-explosive nature of the volcanic eruptions making the volcano safe and accessible for visitors and scientists to view while in eruption. The comparative simplicity of the geology, the large size, and the frequent, voluminous, nonviolent eruptions make both Mauna Loa and Kilauea ideally suited for studying the fundamental processes of volcanism and as an attraction to sightseers.

Because of the favorable opportunities afforded by the volcanoes for fundamental and detailed scientific research, the Hawaiian Volcano Observatory was established on the rim of Kilauea Caldera in 1912. In order to preserve the unique features of the volcanoes and areas of scientific, historical, archeological, scenic and recreational value, Hawaii Volcanoes National Park was established under the administration of the National Park Service in 1916.

Public use of the park is yearround and averaged 3436 persons per day in 1972. Visitors to the park are 90% day visitors and come from three basic sources; off island visitors about 50%; local island residents, about 35%; and Kilauea Military Camp visitors, about 15%. Most of the visitors are generally in the park between mid-morning and mid-afternoon and generally make only a brief trip around Kilauea caldera and a stop at the visitor center to see a film or hear a naturalist talk, lunch at the Volcano House, and back to their bus or car to continue their trip to Hilo or Kona. Many of the local residents come to picnic, sightsee, hike, and to a limited extent, to camp and fish. Their use is almost entirely during the day. The visitors to the Kilauea Military Camp are often families who tend to remain in and around the major developed areas. The camp provides a complete, week-long vacation program for active and retired members of the Armed Forces and their families, and can accomodate 300 persons.

The area selected by the Park Service and the Geological Survey on both scientific and aesthetic grounds for the drill hole lies about 0.7 miles south of Halemaumau within an existing gravel pit (lapilli and ash) that has been operated intermittently by the Park Service as a source of road metal and aggregate.

About 20 feet of gravel has been removed from this pit and it is estimated that a depth of 15 feet of gravel remains. The pit can be reached by an existing service road that leads from near the southernmost point of Crater Rim Road circling Kilauea Crater. The gravel pit road is closed to the general public, as is a large section of the Crater Rim Road that was inundated by the lava flow from the September 1971 Halemaumau eruption. An "invitation to bid" to repair the Crater Rim Road was released on November 6. After the contract is awarded to the lowest bidder, the contractor will have 50 calendar days to complete the repair, so it is estimated that the road will again be in service in February, 1973.

Kilauea volcano is traditionally the home of Pele, Goddess of the volcanoes, and the Kilauea summit was held sacred by Hawaiians who made offerings to the Goddess and honored their dead by depositing bodies in the summit crater. All stones, vegetation, and natural features were sacred and the profanation of their sacredness was held to be extremely dangerous to the well-being of individuals and the equilibrium of society. To disturb these objects was kapu or taboo, and punishable by death to the offender.

The drilling of the scientific test hole is in no way meant to demean or desecrate the sacredness of the summit of Kilauea, but is only designed to learn in more detail the inner workings of the volcano for the betterment of mankind. All precautions will be enforced to assure that a minimum of ground is disturbed and the drill site will be blessed and approved by a Kahuna (a recognized Hawaiian priest). In recognition of the historically sacred nature of Halemaumau, the drilling location was selected at a site 0.7 mile distant.

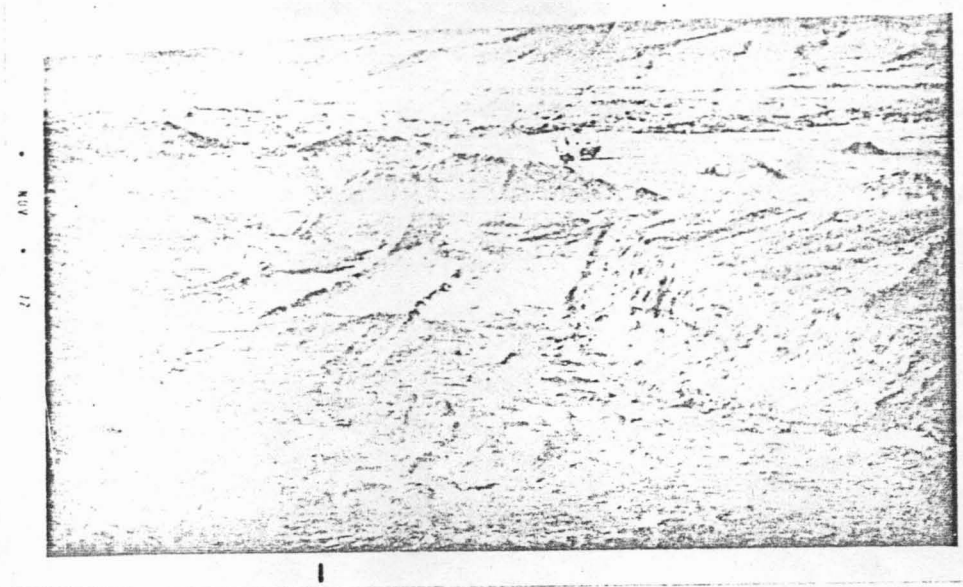

Figure 2. - View looking west across gravel pit. Truck occupies approximate location of proposed drill site. The September, 1971 lava flow from Halemaumau Crater is shown in background. Note visible fumes from Halemaumau Crater.

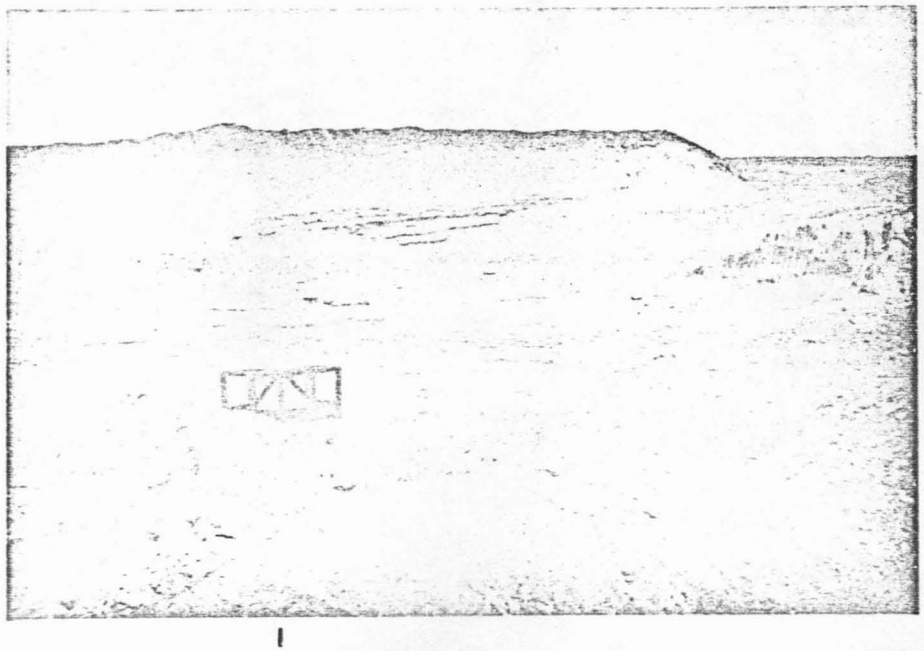

Figure 3. - View looking north across gravel pit. Area proposed for placement of the drill rig is in foreground just beyond table.

Climate

The area of interest on geophysical grounds for the drill hole lies about two thirds of a mile almost due south of Halemaumau Crater (see Figure 1). This area fortuitously lies in the Kau Desert, a vast area of light rainfall and sparse vegetation created by the rain shadow of the summit of Kilauea, the fume belt from the still steaming Halemaumau Crater, and the prevailing northeasterly trade winds. Rainfall at the Volcano House on the north rim of Kilauea Caldera averages 100 inches per year, yet only three miles away in the vicinity of the area of interest the average is 40 inches per year and six miles southwest from the Volcano House the average is 20 inches per year.

Vegetation

In the Kau Desert vegetation is very sparse consisting mainly of grasses, pukiawe, Aalii, lichens, Ohelo, Dubautia, Kupaoa and Ohia Lehua. In the area selected for the drill site there is practically no vegetation.

Wildlife

Wildlife is also sparse, but the Kau Desert area is probably visited occasionally by feral pigs and goats as well as several species of birds. The area of the gravel pit has been inspected by the Park naturalist and certified to have no nests or faunal life, nor are tracks of feral animals present.

Archeological sites or sites of historical interest

Approximately 5 miles southwest of the drill site in the Kau Desert are fossil footprints left in 1790 by warriors of Keoua's army who were asphixiated by gases released by an explosive eruption of Halemaumau while on their way to battle the forces of Kamehameha. The destruction of these warriors by the volcano was a factor in the eventual rise of Kamehameha as ruler of all Hawaii. In the area of the gravel pit, there are no known archeological sites or areas of historical interest.

Geology

Kilauea Volcano is the most studied and best known volcano in the world, although there are still many questions that need to be answered about its internal operation. It is built up entirely of many alternating layers of basaltic flows and ash which rise from the floor of the Pacific Ocean and along with the volcanic flows of Mauna Loa, Mauna Kea, Hualalai, and Kohala have built up the island of Hawaii. The magma that feeds the vent at the summit of Kilauea and along its east and southwest rift zone is believed to originate at a depth of below 40 kilometers beneath sea level. From this origin it rises to the surface through a conduit system to fill a magma reservoir system believed to be about 3 kilometers deep. Upwelling of lava inflates the summit until mounting pressure within the expanding reservoir finally drives the magma into dikes. When one

of these dikes reaches the surface an eruption ensues. The lava may also expand laterally along one of the rift zones of the volcano from the upper magma chamber resulting in a flank eruption.

The theory of a hydrothermal convective cell is quite simple. Water present above hot rocks or a magma chamber is heated, and as its density decreases, it starts to rise through permeable rocks above it. After it rises a distance above the permanent water table, it spreads out horizontally where there is free pore space and less pressures to confine the system. As it cools, it percolates downward to ultimately complete the convective cycle.

There are several possibilities of the geologic or hydrologic environment the drill hole may encounter. One possibility is that the hole will penetrate a monotonous series of volcanic flows and ash deposits with very little or no free water. A second possibility is that the high permeability of the basalt and ash will allow water to circulate freely above the magma chamber such that the water does not superheat but circulates in a broad convective cell, never attaining a high enough temperature for steam to be present. Evidence for this type of geothermal system is supported by elevated temperatures found in some water wells on the island of Hawaii. The existence of the Ghyben-Herzberg lens, a phenomenon created by rain water which seeps through

the porous and permiable rocks of the volcano to float on the surface of more dense sea water at depth demonstrates the high permeability of the volconic rocks and lends support to the unconfined convection cell theory. A third possibility is that through solution and deposition of silica and other minerals, the convection cell can become sealed allowing steam under pressure to accumulate.

It is also possible that water may not exist above the magma chamber due to the very potent supply of heat. Percolating water above and along the hot margins of the magma would be vaporized to steam and expelled through Kilauea's fault and fumarole system. Still another possibility to be considered is that of the hole intersecting a dike or sill of molten rock.

III ENVIRONMENTAL IMPACT OF THE PROPOSED ACTION

Primary Impact

The impact on the environment of drilling the proposed hole should be minimal. The area will suffer by increased traffic on the existing roads due to the movement of men and machinery, chiefly during installation of equipment, changing of drilling crews, and the installation of various monitoring equipment. The bottom of the gravel pit will be leveled to allow installation of the drill rig, however, this will represent an improvement over the existing devastated condition of the pit area. The nature of the construction and landscape are such that they lend themselves to restoration of the area to better than present conditions at the completion of the drilling program.

The behavioral patterns of a few animals might be altered by the introduction of men and machinery, but due to the barren nature of the area and the paucity of wildlife in the immediate vicinity, this effect is expected to be almost non-existent.

The visual impact of the drill rig is expected to be minimal. The gravel pit is now about 20 feet deep, dug in lapilli and ash. The pit lies below a slight rise from the Crater Rim Road and from the parking area for the overlook of Halemaumau Crater, the nearest access to the area for the general public at the present time. The gravel pit is 3,200 feet from this overlook and it may be possible to see the top of the rig if one looks carefully from this point. The site area is in the opposite direction of the major attraction, Halemaumau Crater, however, so that unless it is pointed out by a tour guide, it will probably go unnoticed.

The drill site is over 3 miles from the Volcano House on the north side of Kilauea Crater and 1.8 miles from the overlook of the crater at the Hawaiian Volcano Observatory, and the top of the rig would probably be visible from these points on a clear day with the aid of binoculars, provided the wind was in the right direction and the area is not obscured by fumes. The drill site area is 1.4 miles from the Kau Desert trail and would probably be visible from points on the trail without the aid of binoculars. The duration of the actual drilling will be short, three to six months, so this impact is minimal and transitory. Noise impact created by compressors and drilling operations is expected to be minimal at areas visited by the general public. If the Crater Rim Road is repaired before completion of the drilling, the top of the drill rig may be visible from some points on the road, particularly near the topographic low on the southernmost point on the road.

Accidents, although not probable, are possible during the drilling of the well, Such possible accidents could include well blowout from steam pressure or blowout from pressure released by the drill hole intersecting a dike or sill of molten rock. Stringent precautions will be taken throughout the various operations to ensure against such an accident.

At the completion of the project, the site is to be restored to the original condition or better. The only remaining effect will be the concrete collar of the hole, less than 2 feet in diameter, standing about a foot above the ground surface. However, as the collar will be in the low part of the gravel pit, it will not be visible from the Crater Rim Road. The collar will remain accessible for future scientific studies, but no other signs of the drilling will remain.

As the gravel pit lies in the fume belt of Halemaumau, noxious gases may be a health hazard to the drillers during certain wind conditions. It may be necessary during certain adverse conditions for the drilling crew to wear gas masks or to shut down until conditions improve.

A Gas Analysis from Kilauea is as follows:

Gas	Percent
Water Vapor	70.75
Carbon Dioxide	14.07
Carbon Monoxide	0.40
Hydrogen	0.33
Nitrogen	5.45
Argon	0.18
Sulfur Dioxide	6.40
Sulfur	0.10
Sulfur Trioxide	1.92
Chlorine	0.05

Secondary Impacts

The results of the scientific test hole will be reviewed very carefully by the National Science Foundation to determine the value of funding the more ambitious proposal submitted by Dr. George Woollard of the University of Hawaii known as "Power from the Extraction of Lava Energy" or project "PELE". This proposal involves geological and geophysical surveys to determine the most likely sites for development of geothermal power in Hawaii, as well as deep drillings to confirm more precisely the true nature of the volcanic environment from which energy is to be extracted. The program also involves a study of the technological, geophysical, societal, economic, and environmental feasibility of geothermal power in the islands.

The results of the test hole will also be watched closely by oil companies and the electric power industry interested in developing geothermal power as a source of clean and cheap electrical power in the Hawaiian Islands. Any commercial development of geothermal power would have to be carried out on private lands, however, as there is no possibility of its development in the National Park.

IV MITIGATING MEASURES INCLUDED IN THE PROPOSAL ACTION

1. Location of the drill site

The location of the drill site was carefully selected by the Park Service on grounds of aesthetic suitability and minimum environmental impact on fauna, flora, and natural features of the Park and in recognition of the historically sacred importance of Halemaumau. The specific area of the drill rig will be blessed by a Kahuna to assure that the religious aspects of Kilauea's summit to the Hawaiian people are respected. The area of the site can be reached by existing roads that are closed to the general public. Even after repair of the Crater Rim Road scheduled for February 1973, the road to the gravel pit will remain closed to the public.

2. Placement of the drill rig

The drill rig will be placed on the floor of an existing gravel pit where a minimum of leveling will be needed in already disturbed ground. All associated drilling equipment and machinery will be temporarily stored on the floor of the pit adjacent to the drill rig. During site preparation and throughout the drilling operations, precautions will be taken to insure that a minimum amount of land will be disturbed.

3. Construction of the sub-cellar and site restoration

The floor of the pit will be excavated to allow construction of a structure to house an entry valve to the drill hole. This valve and structure will be completely below grade and the area

will be returned to better than original condition after well completion and demobilization of the drill rig. All restoration will be done to the satisfaction of the Park Service. Entry to the well will be provided for an indefinite period of time to allow experimentation and instrumentation as needed.

4. Drilling medium

Because of the high permeability of the volcanic flows and ash beds, water based muds cannot be used as the drilling medium, therefore, no catchment or holding ponds need to be constructed. A chemically-stabilized foam will be used, insofar as possible, as the drilling medium. This foam can be dispersed chemically after demobilization of the drill rig. Air drilling may be necessary if problems are encountered with the use of foam in a moderate to high temperature environment.

5. Blowout prevention

Stringent precautions will be enforced throughout the various operations to ensure against a blowout. The well head will be fitted with a blowout preventer stack for pressures up to 2000 psi and associated safety equipment to insure control of the well in case extremely high pressure zones are penetrated. At least 200 feet of 20 inch anchor casing will be installed and firmly cemented in competent rock. Additional 16 inch and 12 inch casing will be installed below this depth and cemented as necessary. The hole is planned to be cased to the full depth. If extremely high

temperatures or pressures are encountered, 60,000 gallons of water will be kept on hand in the event it becomes necessary to use mud to quench steam flow from the well. The chief driller for Union Oil Company, the principal driller at the Geysers geothermal field in California, will be available as a consultant to the project to advise in any phase of the operation.

6. Monitoring

Temperature is the most important single measurement to be made. In order to preclude the possibility of intercepting molten rock, bottom hole temperature measurements will be made between all drilling shifts. Continuous temperature logs will be run with other geophysical well logs. Temperatures will be monitored in the nearest fumaroles to the drill site to determine changes that may be related to drilling. Microseismicity will be monitored before and during drilling to help in determining changes brought about by an introduction of cooler material, the drilling medium, into hot rocks. This will give an indication of the temperature environment of the drill bit.

7. Timing of the drilling

The drilling is scheduled for March through August 1973.

V ANY PROBABLE ADVERSE EFFECTS WHICH CANNOT BE AVOIDED

Adverse effects should be avoided with proper drilling and monitoring procedures.

VI THE RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY.

All impacts of the drilling project are positive in the long-term productivity of man's environment. The knowledge gained from the drill hole could have a very positive effect in stimulating the exploration and utilization of geothermal

power in basaltic terrains throughout the world. At the present time all power in the Hawaiian Islands is dependent on imported fossil fuel- chiefly oil, which is shipped long distances for distribution and has the high impact of possible spills and atmospheric contamination from combustion. Since the fuel is imported, it has an additional economic impact on the balance of trade of the islands, and indeed, in this case, the entire United States. The rates charged for the power in the Hawaiian Islands are disproportionate to any other area of the United States, being over 200% of the rates charged in some areas of the mainland. With the advent of cheap electric power, industrial development could be possible as a supplement to the present economy of tourism and agriculture on the island.

Perhaps the greatest positive benefit that the drill hole will have is in advancing scientific knowledge of volcanoes in general. Scientists will gain new insight into the internal structure of volcanoes which could be gained in no other way. The drill hole may allow access to an area believed to be close to the magma chamber for installation of such instruments as in-hole seismometers, strain gages, tilt meters, temperature sensors, etc., which could advance both the knowledge of the

internal workings of the volcano and aid in the prediction of impending eruptions.

VII ANY IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES WHICH WOULD BE INVOLVED IN THE PROPOSED ACTION.

There are no irreversible or irretrievable commitments of resources involved in the proposed action.

VIII ALTERNATIVES TO THE PROPOSED ACTION

A. Use other methods of investigation

Various methods of exploring beneath the surface are available, these include seismic investigations, tiltmeter or precise distance surveys, electrical surveys, gravity surveys, aeromagnetic surveys, etc. Unfortunately, although most of these surveys have been utilized in the investigation of Kilauea volcano, none of them can give an unequivocable or unique answer to conditions that exist above the magma chamber of the volcano.

B. No drill-hole

In the absence of the proposed testing program, information on the hydrologic conditions above a magma chamber in basaltic terrain would have to await a commercially oriented effort to drill for geothermal steam from private lands. This would preclude securing preliminary geothermal data as well as

scientific data on the Kilauea volcano. Related data on environmental impact analysis and evaluation would then have to await a full scale operation, or for funding of project PELE.

IX CONSULTATION AND COORDINATION WITH OTHERS

Three interagency meetings were held between the Geological Survey and National Park Service to discuss the environmental impact of the proposed drill hole. A record of these meetings is attached as Appendix "D". As a result of these meetings, the decision was reached to prepare the preceding assessment of the environmental impact.

Attendants at those meetings included:

Henry W. Coulter	Assistant Director for Environment and Conservation, Geological Survey
Richard S. Fiske	Chief, Office of Geochemistry and Geophysics, Geological Survey
Robert M. Linn	Chief, Scientist, Office of Natural Science Studies, National Park Service
Peter Popenoe	Geologist, Geological Survey
Herbert G. Stewart	Special Assistant for Environmental Analysis, Office of the Director, Geological Survey
J. Robert Stottlemyer	Chief, Division of Federal Agency Coordination, National Park Service

In addition to the above meetings, the following individuals were consulted on the environmental implications of the proposed drill hole.

Robert L. Christiansen	Geologist, Hawaiian Volcano Observatory, Geological Survey
D. Bryan Harry	Superintendant, Hawaii Volcanoes National Park, N.P.S.
Glen F. Kaye	Park Naturalist, Hawaii Volcanoes National Park, N.P.S.
Dallas L. Peck	Geologist, Geological Survey
Donald W. Peterson	Scientist-in-charge, Hawaiian Volcano Observatory, Geological Survey
Robert I. Tilling	Geologist, Hawaiian Volcano Observatory, Geological Survey
John D. Unger	Geophysicist, Geological Survey
Donald E. White	Geologist, Geological Survey
C. J. Zablocki	Geophysicist, Hawaiian Volcano Observatory, Geological Survey

APPENDIX B

Letter Agreement

Drilling Project at Kilauea Volcano, Hawaii

The drilling project at Kilauea is being submitted as a proposal to the National Science Foundation by George V. Keller of the Colorado School of Mines. The following statement outlines the respective rights, responsibilities, and duties among Keller as Principal Investigator, the Geological Survey, and the National Park Service.

George Keller, as Principal Investigator, will have all responsibility and authority regarding administration of the drilling contract and borehole testing subcontracts. This includes drawing up contracts, arranging for advertising and awarding bids, all handling of finances, personnel, equipment, and supplies, and for seeing that terms of contracts and subcontracts are fulfilled. The Principal Investigator bears sole responsibility for assuring that drilling procedures are effective and safe and that all proper drilling practices are followed. The Geological Survey and National Park Service incur no liability or obligation in the event of accident or injury to persons or equipment.

The project will be carried out with close cooperation and under the scrutiny of the Geological Survey. The proposed drilling site lies within Hawaii Volcanoes National Park, and the project must have the approval of the Park Superintendent. Approval will depend on the close involvement of the Geological Survey. While the Principal Investigator will have the responsibility for proper conduct of the drilling, the project will be under the general surveillance of the Geological Survey, and all aspects of the operation must be carried out to its satisfaction.

The Geological Survey and the National Park Service have the right to review and approve contracts and subcontracts. The Geological Survey will provide advice to the Principal Investigator on selection of the drilling site, and the Principal Investigator will make the actual site selection. The site selected must be approved by the Geological Survey on scientific and technical suitability and by the National Park Service on environmental and esthetic suitability. All contracts will include provisions for protecting natural features at the site and for assuring that work at the site and transportation to and from the site will be carried out in a manner agreeable to the National Park Service. The National Park Service will enforce the terms of site protection.

Studies of resistivity prior to and during the drilling will be conducted by the Principal Investigator with possible collaboration of Geological Survey personnel. A seismic noise survey prior to drilling and possible additional seismic studies during and after drilling will be conducted by the Geological Survey under the supervision of J. D. Unger of Hawaiian Volcano Observatory, with possible assistance of members of National Center for Earthquake Research in Menlo Park. The Geological Survey agrees to carry out any reasonable seismic studies requested by the Principal Investigator.

Included in his responsibility for proper drilling procedures, the Principal Investigator is responsible for adequate core recovery. The Principal Investigator will provide a responsible person at the drill site to recover the core, to accurately label the footage on every piece

After completion of the drilling, both the Principal Investigator and the Geological Survey will have the right to use the hole for conducting various kinds of tests. Such possibilities include the testing of in-hole instruments being developed by the Geological Survey. Data gathered by such post-drilling operations will continue to be shared by both parties, but the party conducting the operation will reserve publication rights.

In a general sense, the chief interests of the Principal Investigator include information on the fluid circulation patterns and temperature regime as related to the hydrothermal system, and his rights and responsibilities include resistivity and electrical studies. The chief interests of the Geological Survey include chemistry, petrography, and petrology of the recovered core, and sampling and analyses of pore fluids, and it retains rights and responsibilities for all seismic studies. Data collected by each party will be fully shared with the other, and collaboration on collecting some of the data is expected. Data received from the other party will be privileged and will not be released in any form without prior approval of the party that acquired the data. Publication rights are reserved to the party that collected the data. Due credit is to be given for shared duties and participation, and coauthorship is to be available when appropriate.

John P Albers
Acting Chief Geologist
3/6/72

George V. Keller
George V. Keller

COLORADO SCHOOL OF MINES GOLDEN
A UNIVERSITY OF MINERAL RESOURCES COLORADO
80401

APPENDIX C

DEPARTMENT OF GEOPHYSICS 303-279-3381

November 11, 1972

INVITATION TO SUBMIT COST ESTIMATES FOR DRILLING AT KILAUEA VOLCANO, HAWAII

This notice constitutes an invitation to submit a cost estimate covering drilling of an exploratory core hole at Kilauea Volcano, Hawaii. The drilling will be done for and under the direction of the Colorado School of Mines, Golden, Colorado. Cost estimates, in duplicate, should reach the Colorado School of Mines during the business day of December 4, 1972, to be considered.

The purpose of the drilling project is to obtain for the Colorado School of Mines (CSM) cores together with sludge and cuttings as required from rock formations near Kilauea Caldera, within Hawaii Volcanoes National Park, and to provide for taking temperatures, fluid samples and other measurements in the drill holes by CSM representatives.

The site of the core hole is located on the floor of a small gravel pit located 0.7 miles south of Halemaumau (the location may be found on the Kilauea 1:24000 quadrangle, published by the U. S. Geological Survey; a copy of a portion of this map is attached). The gravel pit has been operated intermittently in the past by the Park Service as a source of road metal and aggregate, and it can be reached by an existing service road that is not open to the general public. It is planned that the drilling rig will be set up on the flat floor of the gravel pit, and that all of the associated drilling equipment will be temporarily stored on the floor of the pit, adjacent to the drilling rig.

Total depth of the hole is planned to be between 3000 and 3500 feet. Material to be drilled will consist of basalt flows and ash. It is possible that high temperatures will be encountered, and that steam under pressure may be present in the rock. It will be necessary for the driller to instal a blowout preventer and associated safety equipment for pressures up to 2000 psi.

It is planned that a surface string of casing of 20 inch diameter be installed to a depth of at least 200 feet in competent rock, and cemented. The driller should be prepared to instal up to two strings of conductor pipe, with diameters of 16 inches and 12 inches, if hole conditions require such a procedure, with cementing to be carried out as required by CSM. We plan to leave the hole cased to full depth. An entry valve contained in a structure that will be completely below grade after completion of demobilization must be provided.

Drilling will be done with chemically-stabilized foam, insofar as possible. Cores will be taken over much of the hole, at intervals designated by CSM. Coring is to be done with Rucker Hycalog coring bits and barrels, to be provided by CSM. The core barrel will be heavy-wall, 6-7/8" OD x 3-1/2" ID. Adequate supplies of compressed air must be provided by the driller to clear holes of the diameters required here. In addition, a reserve of 60,000 gallons of water must be maintained in the event that it becomes necessary to use mud to quench steam flow from the well.

Because the drill site is located in a National Park, every effort must be made to avoid disturbing the drill site unnecessarily and to return the drill site to a condition acceptable to the National Park Service on completion of the drilling.

Drilling is to be carried out on the basis of a 16 to 18 hour work day, six days per week. The shut-down period each day is to be used by CSM personnel to make temperature and other physical measurements in the bore hole. In addition, CSM may require the driller to stand by and provide assistance during geophysical logging operations.

We request cost estimates for such a drilling project, with the following categories of charges itemized:

1. Charges made on an hourly or daily basis, beginning after mobilization is complete and ending before demobilization begins. This rate will cover all time spent in drilling, casing, cementing, coring, reaming, fishing (if not caused by negligence), water haulage and any phases of work normal to this type of operation. Repair, maintenance and overhaul of rig may be included, but not to exceed 30 minutes per day.

2. Lump sum mobilization, including transfer of equipment to drill site, and preparation of site for drilling. Any special equipment and charges of a non-recoverable nature should be included here and itemized.

3. Lump sum demobilization including cost of restoration of drill site to a condition acceptable to the National Park Service.

4. Basis for charges for supplies and materials. Because of the remote location of the drill site, the driller must have adequate supplies and spares on hand. This item should include the basis for determining salvage value of supplies and materials retained by the driller at completion of the project.

5. Charges for standby time, as requested by CSM representatives.

6. Other items of cost not included in the above listing.

In addition to the cost estimate, we request that the following information be supplied:

1. A description of the equipment to be used, including draw-works capacity, air compressor capacity and other pertinent characteristics.

2. The complement of personnel to be assigned to the project.

3. The name of the project manager, and a brief resume of his experience as related to this project.

Cost estimates should be mailed in a sealed envelope marked "Kilauea Drilling Project", and addressed to G. V. Keller, Department of Geophysics, Colorado School of Mines, Golden, Colorado, 80401.

Kilauea drill-hole file

COLORADO SCHOOL OF MINES GOLDEN
A UNIVERSITY OF MINERAL RESOURCES COLORADO
80401

DEPARTMENT OF GEOPHYSICS 303-279-3381

November 9, 1972

Dr. Donald Peterson
U. S. Geological Survey
Hawaii Volcanoes N.P
Hawaii

Dear Don:

I have been discussing our coring plans with various experts for the last month or so, and have decided to use coring equipment supplied by Rucker Hycalog, Inc. This particular type of core barrel is supposed to give better results in basalts than the Christensen rubber-sleeve coring device I originally planned to use, and moreover, it is cheaper. We are mailing out requests for cost estimates today to various drilling companies that we might expect to be able to do the job, and will make a selection on December 4. This should allow us to start preparation of the drilling site by late January. Are there any further steps to be taken at this time to assure that we have permission to drill?

I am taking leave from teaching for the Spring semester, and plan to bring my family to Hawaii around January 20th. We are thinking of living in Hilo. Do you know of anything for rent either in Hilo or nearer the Park?

I would like to spend a couple days in Hilo firming up our arrangements, and have made reservations to arrive on Sunday, November 26. Would it be convenient to you for me to visit with you on Monday or Tuesday?

Sincerely,

George

George V. Keller

GVK/o

APPENDIX D

October 25, 1972

Memorandum

To: The Record

From: Chief, Office of Geochemistry and Geophysics

Subject: Interagency meeting between the U.S. Geological Survey and the National Park Service to discuss the environmental implications of the research drill hole on Kilauea Volcano, Hawaii, being funded by the National Science Foundation.

On Thursday, October 12, 1972, from 2:00 to 3:30 p.m., an interagency meeting was held in the Office of Geochemistry and Geophysics, 4217 GSA Building, to discuss the research drill hole that is planned near the summit of Kilauea Volcano, Hawaii, and the implications of drilling this hole with regard to the National Environmental Policy Act. The research drill hole is being funded by the RANN Program of the National Science Foundation (NSF Proposal No. P2I3232), and the Principal Investigator in charge of the project is Professor George V. Keller of the Colorado School of Mines. In a letter dated May 5, 1972, from the Director of the Geological Survey to Dr. Jesse Denton, formerly with the Division of Advanced Technology Applications, NSF, the Geological Survey expressed its strong interest in the proposed research drill hole and offered to assume the responsibility of preparing an environmental impact statement relating to the hole.

The entire research project will take place within Hawaii Volcanoes National Park, and it is therefore appropriate that representatives of both the Geological Survey and the National Park Service meet to discuss this matter. Present at the meeting were the following agency representatives:

Henry W. Coulter	Deputy Assistant Chief Geologist, Engineering Geology, Geological Survey
Richard S. Fiske	Chief, Office of Geochemistry and Geophysics, Geological Survey
Robert M. Linn	Chief Scientist, Office of Natural Science Studies, National Park Service

Peter Popenoe	Geologist, Geological Survey
Herbert G. Stewart	Special Assistant for Environmental Analysis, Office of the Director, Geological Survey

Dr. Fiske initiated the discussion by outlining the local geology and describing the site where the proposed hole would be drilled. The site is located on the floor of a small gravel pit located 0.7 miles south of Halemaumau, the conspicuous crater lying within the summit caldera of Kilauea Volcano. The gravel pit has been operated intermittently by the Park Service as a source of road metal and aggregate, and it can be reached by an existing service road that is off limits to the general public. It is planned that the drilling rig will be set up on the flat floor of the gravel pit, and that all of the associated drilling equipment will be temporarily stored on the floor of the pit, adjacent to the drilling rig. The configuration of the nearby ground is such that the floor of the gravel pit and the drilling platform will not be visible from localities open to Park visitors. The top of the drilling mast will extend upward above the surrounding topography, but it probably will be visible from tourist areas only with the aid of binoculars. The drill rig and related equipment will be on the site for an estimated 3-6 months.

The research drill hole is intended to investigate what is suspected to be a convection cell of hot water above the magma chamber of the volcano. The geophysical expression of the convection cell is a broad resistivity low coinciding with an area of seismic noise at a depth of approximately 1 km. An area of high microearthquake activity at a depth of 3 km is believed to mark the top of the magma chamber.

The discussion then moved to various technical aspects of the project that are being planned by Professor Keller. Through the courtesy of Mr. Carel Otte of the Union Oil Company, the head geothermal driller of Union Oil will be available as consultant to the project. Approximately the upper 1000 feet of the hole will be drilled to 10-3/8" diameter to allow setting of casing and a pressure control valve capable of withstanding 2000 psi. The remainder of the hole, which will be from 3000 to 5000 feet in depth, will be drilled to 8-3/4" diameter. In order to minimize the necessity of water haulage to the drilling site, a special chemical foam will be employed as the drilling medium. Because of the high permeability expected in the subsurface, little, if any, circulation of this foam to the surface is expected, and therefore the problem of disposal of well cuttings will be minimal. Parts of the hole will be cored; this core will become the property of the U.S. government and will be stored at the Hawaiian Volcano Observatory for later detailed study.

The possibility exists that the hole will penetrate part of the magma reservoir that is interpreted to lie at relatively shallow depth beneath the summit of the volcano. Dr. Fiske explained that experience from

two dozen shallow research holes drilled into the liquid core of Kilauean lava lakes by scientists of the Hawaiian Volcano Observatory in the past 12 years does not suggest specific environmental problems will arise.

Several unresolved environmental considerations were pointed up in the discussion. How the casing will be cemented in view of the high porosity of the volcanics, and will 1000 feet of casing indeed be enough? How will the hole be abandoned? Is an entry valve to be provided or will the hole be permanently plugged? What is the depth of lapilli in the pit at the present time and what sort of structure will be necessary for placement of the rig and pressure valve? What are the secondary environmental implications for geothermal development outside of the Park if a high temperature convection cell of commercial quality is encountered by the research drill hole?

Peter Popenoe was named to resolve these questions prior to consideration of whether the environmental impact of the project would be sufficiently small to justify the preparation of a Negative Declaration rather than an Environmental Impact Statement.

Richard S. Fiske

RSFISKE:jcb
cc: Director's Read
ACG Reading
Geochem & Geophys

United States Department of the Interior

GEOLOGICAL SURVEY
WASHINGTON, D.C. 20242

December 11, 1972

Memorandum

To: The Record

From: Chief, Office of Geochemistry and Geophysics

Subject: Environmental considerations related to research drill hole on Kilauea Volcano, Hawaii

On Thursday, November 16, 1972, from 3:00 to 3:45 p.m., an interagency meeting was held in the office of Dr. Robert M. Linn, National Park Service, for the purpose of discussing environmental questions related to the NSF-funded research drill hole that is planned to be drilled on Kilauea Volcano, Hawaii. Present at the meeting were the following agency representatives:

Henry W. Coulter	Assistant Director for Environment and Conservation, Geological Survey
Richard S. Fiske	Chief, Office of Geochemistry and Geophysics, Geological Survey
Robert M. Linn	Chief Scientist, Office of Natural Science Studies, National Park Service
J. Robert Stottlemyer	Chief Division Federal Agency Coordination, National Park Service

At the meeting, many points were discussed which had previously been raised in the previous interagency meeting held on October 12, 1972, and which had been discussed in the October 25 memo to the Record from Richard S. Fiske, Chief of the Office of Geochemistry and Geophysics, Geological Survey, and in the November 15 memo to the Record from Peter Popenoe, Geologist, Geological Survey. Three important points were emphasized:

1) the proposed drilling venture is a "one-time" project, there are no plans for a followup drilling program

2) because the drilling is to take place in Hawaii Volcanoes National Park, there is no possibility that an attempt will be made to exploit thermal energy from this drill hole in the event that a favorable geothermal reservoir is encountered

3) the drilling will take place on the floor of an existing gravel pit which is reached by an existing Park service road; the local environment will be virtually unperturbed by the drilling activity

Because of the above points, and because the proposed drilling program is not part of a major Federal program, the joint decision was reached that a detailed environmental assessment will be made prior to making the decision whether or not to prepare a full Environmental Impact Statement. Peter Popenoe, Geologist, Geological Survey, will take the lead in preparing the environmental assessment. He has been sent to Hawaii where he will confer with the Superintendent, Hawaii Volcanoes National Park and the Scientist-in-Charge, Hawaiian Volcano Observatory, prior to the preparation of the document.

Richard S. Fiske

Richard S. Fiske

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO : Bob Tilling

DATE: June 10, 1974

FROM : Dick Fiske

SUBJECT: Environmental assessment of the Kilauea Iki drilling

Attached please find a rather formal memo stating that the proposed drilling in Kilauea Iki does not constitute a major Federal action. Apparently this is all I really have to say (it is to be understood that an environmental impact statement is not required). I checked the wording of this memo with Herb Stewart and he thought that everything is in order. So, now you can launch into the actual preparations for the drilling. My only wish is that I could be there to help sling those red-hot drill rods around!

Really looking forward to seeing you and Susan and the kids in early July.

Best regards,

Dick

Richard S. Fiske

Attachment

5010-108

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO : Robert I. Tilling

DATE: June 10, 1974

FROM : Chief, Office of Geochemistry and Geophysics

SUBJECT: Environmental assessment related to proposed drilling program in Kilauea Iki lava lake

I have reviewed the environmental assessment that you and other staff members of the Hawaiian Volcano Observatory have prepared on the proposed research drilling to take place in Kilauea Iki lava lake. It is my determination that this proposed action does not constitute a major Federal action significantly affecting the quality of the human envrionment in the sense of Nepa, Section 102 (2) (C).

Richard S. Fiske

ENVIRONMENTAL ASSESSMENT OF AN INVESTIGATION OF OF THE COOLING OF BASALTIC LAVA IN KILAUEA IKI LAVA LAKE, KILAUEA VOLCANO, HAWAII

Prepared by

U.S. Geological Survey
Hawaiian Volcano Observatory and National Center (Reston)

May 1974

CONTENTS

SUMMARY

1. Type of action (X) Administrative ( ) Legislative

2. Brief description of proposed action

Three 7.6 cm (3-inch)-diameter holes are to be drilled into the solidifying lava lake formed in 1959 in Kilauea Iki Crater, located in Hawaii Volcanoes National Park, Island of Hawaii. This action is a continuation of a drilling program begun in 1960; the last drilling in Kilauea Iki Crater was carried out in 1967-68. The purposes of the drilling are to determine the thickness of the upper crust of the lava pond, to obtain quantitative temperature profiles, and to collect samples from the crust and from the molten lava below it. The drilling is an integral part of the U.S. Geological Survey's study of the cooling and crystallization of basaltic lava, as another facet of a comprehensive program to investigate past and present eruptions of Kilauea Volcano to understand its history, behavior, and hazards, and to better predict its future eruptions.

3. Summary of environmental impact effects

The three drill holes will be located from about 8 to 200 m (25 to 700 ft) away from the hiking trail that leads across the floor of Kilauea Iki Crater. The drilling operation will be visible from the crater rim. Its purpose and scientific importance will be explained to visitors by National Park Service personnel and/or appropriate information signs. The drilling operation, which will last for approximately one month,

will have only brief visual and slight noise impact. No permanent impact, either visual or ecological, will result from the drilling.

4. Alternatives considered

   A. Other means of investigation

   B. No drilling

5. The environmental effects and procedures related to the proposed action have been discussed with the Superintendent, Hawaii Volcanoes National Park, and appropriate officials at the U.S. Geological Survey's Headquarters at Reston, Virginia.

I. DESCRIPTION OF THE PROPOSED ACTION

We propose to drill three 7.6 cm (3-inch)-diameter holes, with projected depths of about 46 m (150 ft) to 120 m (400 ft), in the floor of Kilauea Iki pit crater, located near the summit of Kilauea Volcano, Hawaii Volcanoes National Park, Hawaii. The eruption of November-December 1965 filled this crater with lava to a depth of 111 m (365 ft). A few months after the lava lake formed, systematic research on the behavior and properties of cooling lava was begun by personnel of the U.S. Geological Survey's Hawaiian Volcano Observatory. A key part of this research included drilling into the solidifying lava lake. Eruptive activity during 1963 to 1969 on the east-rift zone of Kilauea also produced ponds of lava in Alae, Aloi, and Makaopuhi Craters and, temporarily, near the main Mauna Ulu vent. As part of the continuing drilling program that began in 1960, each of these lakes was drilled, either with portable core-drilling rig or with a trailer-mounted core-drilling rig capable of recovering 5.7 cm ($2\frac{1}{4}$ inch)-diameter core from a 7.6 cm (3 inch)-diameter drill hole. Table 1 lists all the holes drilled in Kilauea lava lakes by the Hawaiian Volcano Observatory from 1960 on. It should be noted, however, pioneering drilling studies to better understand the behavior of Kilauea Volcano were conducted by the Observatory as early as 1922.

Temperatures are monitored and core recovered as the drilling progresses. When drilling reaches the depth of the crust-melt interface, samples of the still molten basalt are collected. Following the completion of drilling, temperatures are measured on a regular basis (generally biweekly at first and later at successively longer intervals)

until the lava lake cools to ambient temperature. Drilling is the only technique by which quantitative information can be obtained on the rate of solidification and cooling of large ponded bodies of basaltic lava and of collecting still-molten 1959 lava. The drill holes also can be used for periodic collection of volcanic gases, testing of bore-hole instruments, and for other experiments requiring or facilitated by drill holes.

Upon completion of drilling, all equipment is removed and a short segment of 15 cm (6 inch)-diameter steel pipe is installed and cemented as a collar around the hole; the top of the pipe will protrude no more than 20 cm (8 inches) above the ground and will be covered by a protective metal cap. This is not only to comply with established safety standards, but also to reduce heat loss by convecting steam and to prevent contamination of the hole by either accident or vandalism. After completion of drilling, the holes pose no safety hazard to passers-by. In addition to the collar, two inconspicuous anchor bolts, 1.5 cm in diameter and protruding about 5 cm above the surface, remain in place at each drill site. The anchor bolts last used during the 1967-68 drilling will be reused in setting up of the rig for the proposed drilling, thereby virtually eliminating any need for site preparation.

The 15 m-deep lava lake that formed in Alae Crater in 1963 solidified by August 1964 and cooled to ambient temperature before 1968. A project in May 1969 to drill into a new lava pond in Alae that formed in February was aborted by renewed filling of the crater (and burial of the drilling equipment). The new lava that flooded Alae issued from

vents along a new fissure hundreds of meters north and west of the crater; vast outpourings of lava from this vent ultimately built the new volcanic shield Mauna Ulu. The filling of Alae Crater in 1969 was not caused by nor related in any way to the ill-fated drilling project. Similarly, the drilling into a lava pond that formed in Aloi Crater in 1969 was short lived because drilling operations had to be terminated because of increasingly vigorous eruptive activity at the nearby vents. Both the Alae and Aloi lava lakes that formed in 1969 were completely buried by lavas originating at Mauna Ulu, which at the present time is still in active eruption. The 83 m-deep, 1965 Makaopuhi lava lake has also been totally obliterated by Mauna Ulu lavas. Thus, of the lava lakes in existence in 1969, three (Alae, Aloi, and Makaopuhi) have been destroyed by younger lavas, and another (Mauna Ulu) is currently active. Kilauea Iki, last drilled in 1967-68 (see Figs. 1 and 2), is now the only surviving lava lake accessible for continuing the studies on the properties and behavior of cooling lava.

We plan in the fall of 1974 to resume the lava-lake studies begun in 1960. Recent geophysical and geodetic data suggest that the solidification of the remaining melt in the lake is proceeding at a rate considerably faster than had been anticipated from earlier studies. The rapidly shrinking amount of molten material suggests that final solidification is approaching. Hence re-drilling the lake at this time is critical for deriving maximum scientific benefit.

Drilling equipment will be carried to the lake surface (crater floor) by helicopter. Less bulky supplies, such as tools, core boxes, and the like, will be transported via a temporary tramway leading to the site from a remote spot on the north rim of the crater.

The drilling will be carried out by core-drilling techniques using tungsten carbide bits; no cuttings are returned to the surface. Water used to cool the drill will be supplied by means of a 2.5 cm (1-inch)-diameter plastic hose descending the crater wall along side the temporary tramway. Previous drilling experience suggests that water consumption for drilling will likely range from about 500 to 1,000 liters per meter (40 to 80 gallons per foot) of rock penetration depending on temperature. Water used for cooling is dissipated by percolation into the porous lava crust and by evaporation; it does not return to the surface. The work will be performed by U.S. Geological Survey personnel, some of whom were involved in the earlier drilling projects.

II. GEOLOGY

Kilauea is a shield volcano built up of countless thin flows of basaltic lava. The volcano has a summit depression, called a caldera, presumably formed by collapse of the summit in the prehistoric past. Pit craters are smaller collapse features associated with removal of liquid magma from underground conduits. Kilauea Iki is one of the larger pit craters that dot Kilauea's summit and east flank. Eruptions that occur in pit craters build up ponds of lava that are much thicker than the normal flows since they are confined by the crater walls and cannot spread laterally. These sites provide the ideal conditions--in essence a natural laboratory--for studying cooling of basaltic lava.

III. ENVIRONMENTAL IMPACT OF THE PROPOSED ACTION

Primary Impact

During the time that the drilling program is underway, the equipment and the operation will be visible from public viewing sites on the crater rim and from the trail on the floor of the crater. From the rim the equipment will appear similar to the scene illustrated in Figure 1. The drilling mast is about 6.7 meters (22 feet) in height. In addition to the equipment at the site, a tramway cable and a plastic water hose will extend from the north rim of the crater to the floor. All visual impact will be temporary, as all equipment will be removed when drilling is completed. A small collar with metal cap will remain at the site of each hole; the site of an earlier drill hole is shown in Figure 2 as an example of the inconspicuous nature of the mark left by this type of drilling.

A two-cylinder 16-horsepower engine is used to power the drill, and a 9-horsepower engine is used to operate the water pump. Though audible from the crater floor, sounds of the drilling on the rim generally will either be barely heard or completely inaudible with the prevailing atmospheric and wind conditions. Traffic noises on the roads and parking lots on the rim will easily mask the noise from the drilling engine.

One visitor overlook already has a display explaining earlier drilling projects at Kilauea Iki. During the new project, park personnel and/or additional information signs will be able to further explain the work to visitors. Thus the project will augment already-existing National Park interpretive programs.

In summary, the impact on the environment while drilling is in progress will be minimal, and after completion will be essentially nil.

Secondary Impacts

None.

IV. MITIGATING MEASURES INCLUDED IN THE PROPOSED ACTION

1. Locations of two of the three drill sites will be distant from the trail that crosses the floor of Kilauea Iki Crater.
2. Site preparation will be minimal because the drill sites will be adjacent to the 1967-68 holes to facilitate setting up of the drill rig (reuse of the 1967-68 anchor bolts, etc.)
3. The visual and noise impact during drilling will be temporary, lasting approximately one month. Any trash generated by the project will be regularly removed via the temporary tramway. Upon completion of the project, all equipment will be removed and the sites will be left in essentially their natural state. (Figs. 1 and 2).
4. The active drilling phases, though temporary, will have educational value and tourist appeal in that the National Park Service can interpret the drilling operation for visitors while it is underway. It will provide an active demonstration of scientific research in progress.
5. After drilling and initial measurements and sample collection have been completed, the holes can be reentered for additional studies, including the testing of bore-hole instrument systems for investigating the chemical and physical properties of the rocks *in situ*.

6. Studies of re-vegetation of the lake surface were carried out concurrently with the 1967-68 drilling in Kilauea Iki, and no adverse effects on the rate or type of re-vegetation could be determined. The sparsely scattered plants, such as lichens, ferns, and ohia trees, beginning to grow (mainly in cracks) on the floor of Kilauea Iki were not damaged during the project. No animals have yet returned to live on the crater floor since the formation of the lava lake in 1959.

7. Because the 1959 lava-lake surface at Kilauea Iki contains no archeological features, the Pacific Archeologist of the National Park Service has requested and been granted an archeological clearance for the drilling (see Attachments 1 and 2).

8. The experience gained by the personnel of the U.S. Geological Survey during the previous drilling projects provides assurance that the proposed drilling program will be carried out expeditiously and safely.

V. ANY PROBABLE UNAVOIDABLE ADVERSE EFFECTS

Similar projects carried out previously (Table 1) have not caused any adverse environmental effects. This experience indicates that no adverse environmental effects can be anticipated from the proposed drilling program.

VI. RELATIONSHIP BETWEEN LOCAL, SHORT-TERM USE OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The drilling operation is part of a long-term program that is significantly increasing our knowledge of the eruptive processes related to Kilauea Volcano in particular and to other basaltic volcanoes

in general. Its scientific importance has already been demonstrated and publications discussing its results have been favorably received by scientists throughout the world. This has been accomplished without permanent sacrifice of the volcanic environment as a natural resource and attraction, and with only temporary intrusions on the natural scene.

VII. ANY IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES WHICH COULD BE INVOLVED IN THE PROPOSED ACTION

None.

VIII. ALTERNATIVES TO THE PROPOSED ACTION

Use other means of investigation

Certain specialized types of surface geophysical studies can provide some indirect estimates of the thickness of the upper crust of the lava lake. However, to obtain temperature measurements, direct location of the crust-melt interface, and samples of both the crust and residual melt, access through drill holes is the only known technique.

No drilling

This alternative would terminate the unique and highly productive research program on the evolution of ponded basaltic lava lakes produced by Kilauean eruptions that has been in progress by the U.S. Geological Survey for 14 years. No other comparably accessible and well studied lava lakes are known in the entire world.

IX. CONSULATION AND COORDINATION WITH OTHERS

Consultations have taken place between Dr. Donald W. Peterson, Scientist-in-Charge of the Geological Survey's Hawaiian Volcano Observatory, and Mr. G. Bryan Harry, Superintendent of Hawaii Volcanoes National Park, to consider this proposed action. All the foregoing factors were included in their discussions. The action has also been considered by appropriate authorities at the Geological Survey's Headquarters (Reston). All parties consulted concur that the proposed action would not result in any permanent visual or ecologic impact on the natural volcanic terrane.

Table 1. Holes previously drilled in recent years as part of the Hawaiian Volcano Observatory's studies of the crystallization of basaltic lava.

Lava lake	Date(s) formed	Date(s) of drilling	Hole(s)	Maximum depth, meters (feet)
Kilauea Iki	November-December 1959	1960-1962	1	6.8 (22.4)
			2	12.0 (39.2)
			3	12.6 (41.5)
			4	14.6 (48.0)
		1967-1968	1	27.2 (89.2)
			2	29.5 (96.7)
			3	26.5 (87.0)
Alae	August 1963	1963-1966	1	1.7 (5.6)
			2	0.6 (2.1)
			3	4.1 (13.4)
			4	4.7 (15.3)
			5	8.9 (29.2)
			6	9.8 (32.2)
			7	7.1 (23.4)
			8	8.7 (28.6)
			9	16.1 (52.9)
			10	4.9 (16.0)
			11	4.9 (16.0)
			12	14.3 (47.0)
	February 1969	1969	1	2.1 (7.0)
Aloi	Late 1969-early 1970	1970	1	1.8 (6.0)
			2	1.8 (6.0)
			3	1.8 (6.0)
			4	1.8 (6.0)

"Attachment 1"

CITY OF REFUGE NATIONAL HISTORICAL PARK
Honaunau, Kona, Hawaii 96726

May 1, 1974

TO: Chief, Arizona Archeological Center

FROM: Pacific Archeologist

SUBJECT: Archeological Clearance - U. S. G. S. Drill Site on 1959 Eruption floor of Kilauea-iki, Hawaii Volcanoes, HI.

At the request of the U. S. G. S., Kilauea Observatory, Hawaii Volcanoes National Park, Hawaii, I made a brief check on April 26, 1974, of the site at Kilauea-iki crater - a lava floor created by the 1959 eruption of this crater (location map attached). There are no archeological features in the project area. Therefore, I respectfully request that archeological clearance be granted.

(SGD) Sophie K. Gomes
for/ Edmund J. Ladd

co:
HISD
✓ U. S. G. S.
Superintendent, HAVO

EJLadd:skg

"Attachment 2"

United States Department of the Interior

NATIONAL PARK SERVICE

ARIZONA ARCHEOLOGICAL CENTER Tel. No. 602/792-6501
P. O. BOX 49008
TUCSON, ARIZONA 85717

IN REPLY REFER TO:

H22
(WR)PSA

May 10, 1974

056 - HAVO
Clearance No.

Memorandum

To: Superintendent, Hawaii Volcanoes

From: Chief, Arizona Archeological Center

Subject: Archeological Clearance

The effects of the following project on archeological resources have been assessed: U.S.G.S. Drill Site on 1959 Eruption Floor of Kilauea-iki, Hawaii Volcanoes, Hawaii.

The basis for this assessment is: Letter report by Edmund J. Ladd, Pacific Archeologist, dated May 1, 1974, copy enclosed.

X Since there is no substantial evidence that significant archeological resources will be affected adversely, clearance to proceed is hereby provided.

___ Since the identified adverse effects of the project on archeological resources have been mitigated by the completion of appropriate investigations, clearance to proceed is hereby provided.

If concealed archeological resources are encountered during construction, please take all necessary steps to protect them and immediately notify this office so that appropriate action may be taken.

Douglas H. Scovill

Enclosure

cc:
HISD, w/enc.
Pacific Archeologist, w/o enc.

JOHNNY HORIZON 76

Let's Clean Up America For Our 200th Birthday

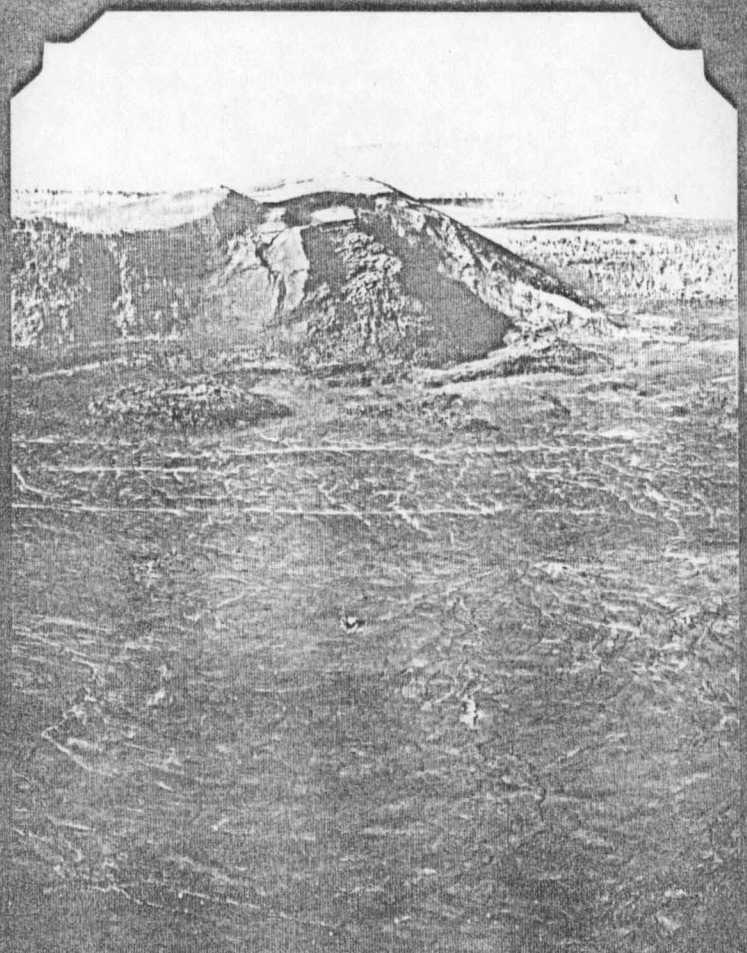

Figure 1A. View from the north rim in 1967 of the lava-lake surface of Kilauea Iki Crater, showing the drilling rig in operation. Basically the same drilling rig will be used in the proposed action.

Figure 1B. View from the north rim in 1974 of the lava-lake surface of Kilauea Iki Crater, showing the minimal impact of the 1967-68 drilling on the lava-lake surface.

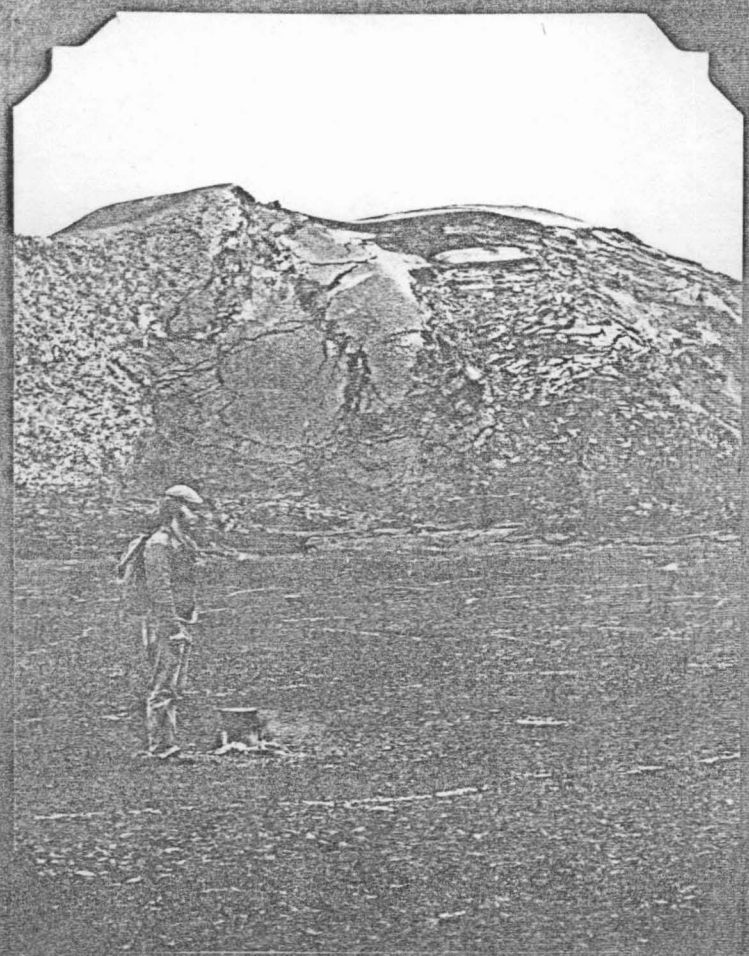

Figure 2A. Closer view in 1974 of one of the 1967-68 capped holes in Kilauea Iki after drilling, showing its minimal impact on the lava-lake surface. The viewing platform on the south rim is approximately 300 m away.

Figure 2B. Close-up view of one of the anchor bolts on the lava-lake surface of Kilauea Iki used in the 1967-68 drilling. These 1967-68 bolts will be reused in the proposed action to minimize site preparation.

Draft: RITilling
May, 1974

ENVIRONMENTAL ASSESSMENT OF A PROJECT TO DRILL A NEW HOLE AT SULPHUR BANK, KILAUEA VOLCANO, HAWAII, FOR STUDIES OF FUMAROLIC GASES

Prepared by

U.S. Geological Survey
Hawaiian Volcano Observatory, Hawaii 96718

CONTENTS

SUMMARY

1. Type of action (X) Administrative ( ) Legislative

2. Brief description of proposed action

One 7.6 cm (3 inch)-diameter hole is to be drilled at Sulphur Bank, located in Hawaii Volcanoes National Park, Island of Hawaii. The action would provide a new, uncontaminated, shallow (15 m or less) hole to replace an existing 52-year old, probably contaminated well in current use for sampling of fumarolic gases of Kilauea Volcano for scientific studies.

3. Summary of environmental impact effects

The location of the new hole would be distant from the heavy-traffic tourist areas, thereby minimizing the possibility of its disturbance or contamination, either malacious or inadvertent, by persons other than authorized scientific personnel conducting experiments. The drilling operations will be partially or wholly visible to park visitors. However, its purpose and scientific importance will be explained to visitors by National Park Service personnel and/or appropriate information signs. Although the drilling operation, planned to last for only a few days, will entail brief, temporary visual and noise impact, no permanent impact, either visual or ecological, will result from the drilling.

4. Alternatives considered

A. No drilling

B. Continue to use present well for gas sampling

C. Use other means of gas sampling

5. The environmental effects and procedures related to the proposed action have been discussed with the Superintendent, Hawaii Volcanoes National Park, and with scientists, both within and outside the Geological Survey, knowledgeable in investigations of volcanic gases.

I. DESCRIPTION OF THE PROPOSED ACTION

We propose to drill one 7.6 cm (3 inch)-diameter hole, no more than 15 m (50 feet) in depth and possibly much less, in the Sulphur Bank area near the northeastern rim of Kilauea caldera, Hawaii Volcanoes National Park, Hawaii. This proposed new hole will supplant the existing well there (one of two drilled in 1922), which, though used for many studies of fumarolic gases of Kilauea Volcano, is now sufficiently contaminated and disturbed to render its scientific value questionable. The primary objective of the proposed drilling project is to provide a fresh, uncontaminated hole more suitably located for scientific studies; the location of the hole will be more distant and less visible from the heavy-traffic tourist areas, hence less susceptible to disturbance and vandalism and more appropriate for studies utilizing gas sampling systems requiring long-term, unattended or automatic operation. A secondary but important objective of the proposed action is that it will serve as a meaningful field test of drilling equipment and for personnel prior to the drilling project in Kilauea Iki lava lake scheduled for the fall of 1974. The Sulphur Bank drilling will commence as soon as an appropriate site within the general Sulphur Bank area is selected and the equipment can be readied.

An important requirement of the proposed hole is to intersect a steady and voluminous source of fumarolic gas, the concentration and flow of which are largely controlled by fracture patterns in the area. Because there is no reliable guide in choosing the precise spot to encounter copious steam, several shallower drilling probes may have to be made before deciding which of the shallower probing holes should be extended to become the main hole.

II. GEOLOGY

Sulphur Bank lies within the caldera complex of Kilauea Volcano, in an area underlain by prehistoric basaltic lava, locally veneered by discontinuous ash deposits of the 1790 explosive eruption of Kilauea. Structurally, Sulphur Bank is situated along one of the principal boundary faults that partially ring Kilauea Caldera. It lies on a bench above the major topographic break that bounds the inner caldera, and is 200 to 400 meters (650 to 1300 feet) back from the main rim. As its name implies, Sulphur Bank has been, and is still, a site of active deposition of sublimates (primarily native sulfur and diverse sulfate minerals) and hydrothermal alteration of the rocks, directly attributable to the passage of volcanic emanations through the fractured ground for many hundreds or thousands of years.

III. ENVIRONMENTAL IMPACT OF THE PROPOSED ACTION

Primary Impact

During the few days that the drilling program will require, the equipment and the operation may be partially or wholly visible (depending on specific drill site) by park visitors

touring Sulphur Bank, even though the proposed hole will be placed at some distance away from the existing well there, which is immediately adjacent to the tourist areas. The drilling mast is about 6.7 m (22 feet) in height. All visual impact, however, will be of very short duration, probably no more than several days, as all equipment will be removed completely upon termination of drilling. Only a short casing, cemented in concrete and capped with a metal cover, will remain to mark the site of the hole. Because the capped casing top presents a very low profile (nearly ground level), the visual impact of the proposed hole will be essentially nil. In contrast, the existing well available for scientific studies is extremely conspicuous visually, not only detracting from the natural landscape but also inviting disturbance by unauthorized persons.

A two-cylinder 16-horsepower engine is used to power the drill, and a

9-horsepower engine is used to operate the water pump. Although the noise during the active drilling phases will be clearly audible to visitors, such noise impact will be temporary. Consumption of water used to cool the drill is expected to be about 500 liters per meter (40 gallons per foot) of rock penetration.

In summary, the impact on the environment during drilling will be minimal and consist mainly of noise generated by the operating equipment for several days. After completion of drilling and removal of equipment, the environmental impact will be virtually nil.

Secondary Impacts

None.

IV. MITIGATING MEASURES INCLUDED IN THE PROPOSED ACTION

1. Location of the drill site will be distant from the visitor viewing areas.

2. The visual and noise impact during the project will be temporary, only lasting for a few days.

3. Site preparation will be minimal as no earth movement is required to set up drill rig. The proximity of the drill site to the water tanks of Hawaii Volcanoes National Park assures ready and easily accessible supply of water to cool the drill while in operation, thereby eliminating the need to establish a temporary water supply system.

4. The active drilling phases, though temporary, will have educational value and tourist appeal in that the National Park Service can interpret the drilling operation for visitors while it is underway. It will provide an active demonstration of scientific research in progress.

5. The short duration and minimal site preparation needed for the drilling reduce any possible disturbance of faunal life in the area. The constant natural emissions of gas have kept plant growth in the area to a low level, and the drilling operation will cause no permanent impact on plant life.

6. Once a new hole is successfully established for investigations of fumarolic activity, it will be possible to close the existing well and restore the area near it to the natural state thereby enhancing the scenic view of Sulphur Bank for visitors.

V. ANY PROBABLE UNAVOIDABLE ADVERSE EFFECTS

Inasmuch as two holes were successfully drilled in the Sulphur Bank area as early as 1922 using cruder equipment, and one of these has safely provided valuable samples of fumarolic gases for a wide variety of studies for more than 50 years, we anticipate no unavoidable adverse effects will result from the proposed drilling.

VI. RELATIONSHIP BETWEEN LOCAL, SHORT-TERM USE OF MAN'S ENVIRONMENT AND MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The new drill hole should materially improve the quality and purity of gas samples collected from fumaroles in the Sulphur Bank area. Sophisticated studies of the uncontaminated gas samples to be collected from the new hole will not only provide continuity with past experiments but will enable the degree of reliability to be established of possibly contaminated samples collected in recent years from the existing well. Thus, the drilling of the proposed hole should significantly increase our knowledge of fumarolic gases associated with Kilauea Volcano, one of the world's most active volcanoes, with no permanent sacrifice of the volcanic environment as a natural resource and attraction.

VII. ANY IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES WHICH COULD BE INVOLVED IN THE PROPOSED ACTION

None.

VIII. ALTERNATIVES TO THE PROPOSED ACTION

No drilling

The alternative of no drilling would require the continued use of the existing, possibly contaminated well for sampling Kilauea's fumarolic gases and/or sampling of such gases be accomplished via natural volcanic orificies or deep fissures at Sulphur Bank or elsewhere. However, appropriate natural openings are few; moreover, they are commonly accessible only with difficulty and more susceptible to natural and/or man-induced disturbance and contamination. On the other hand, continued and better sampling of gases from Sulphur Bank via the proposed new hole would provide continuity and direct comparison with previous studies on material from there via the present, possibly contaminated well.

Continue to use present well for gas sampling

The well currently used for gas sampling is suspected to be disturbed and contaminated. The strong possibility that the gas samples from this well may not be truly representative of the natural fumarolic gases of Kilauea seriously compromises the validity and usefulness of analytical data obtained on such samples and any interpretations derived from them.

Use other means of gas sampling

Although the fumarolic gases could be sampled without recourse to a drill hole, the samples would be diluted to a greater extent with air, making quantitative analyses more difficult and reducing their reliability. A method of sampling that minimizes atmospheric contamination, as is possible in a deep hole, will yield maximum scientific benefit.

IX. CONSULTATION AND COORDINATION WITH OTHERS

Consultations have taken place between Dr. Donald W. Peterson, Scientist-in-Charge of the Geological Survey's Hawaiian Volcano Observatory, and Mr. G. Bryan Harry, Superintendent of Hawaii Volcanoes National Park, to consider this proposed action. All the foregoing factors were included in their discussions. The action has also been discussed with scientists within the Geological Survey and the University of Hawaii, including Drs. Bruce Finlayson (Hilo) and John J. Naughton (Manoa), who have been active in investigations of Kilauean volcanic gases. Several of the scientists have for some time been urging that a new hole be drilled to assure that samples would be uncontaminated. All parties consulted concur that the proposed action would be scientifically valuable and would not result in any permanent visual or ecologic impact on the natural volcanic terrane.